CERES Aqua Beta1 SSF Data Quality Summary

Investigation:	**CERES**
Data Product:	**Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)**
Data Set:	**Aqua (Instruments: CERES-FM4, MODIS)**
Data Set Version:	**Beta1**: **These data products are NOT regarded as publishable and will not be maintained in the archives.**

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Science Team. This document briefly summarizes key validation results, provides cautions where users might easily misinterpret the data, provides links to further information about the data product, algorithms, and accuracy, and gives information about planned data improvements. This document also automates registration in order to keep users informed of new validation results, cautions, or improved data sets as they become available.

This document is a high-level summary and represents the minimum necessary information for scientific users of this data product.

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Nature of the SSF Product

This document discusses the Single Scanner Footprint (SSF) data set version Beta1 for Aqua. Additional information is in the Description/Abstract document. This data set is available only for the CERES FM4 instrument. The files in this data product contain one hour of full and partial-Earth view measurements or footprints located in colatitude and longitude at a surface reference level.

The Aqua SSF is a unique product for studying the role of clouds, aerosols, and radiation in climate. Each CERES footprint (nadir resolution 20-km equivalent diameter) includes reflected shortwave (SW), emitted longwave (LW) and window (WN) radiances and top-of-atmosphere (TOA) fluxes from CERES with temporally and spatially coincident imager-based radiances, cloud properties, and aerosols, and meteorological information from the European Centre for Medium-Range Weather Forecasts (ECMWF). Cloud properties are inferred from the Moderate-Resolution Imaging Spectroradiometer (MODIS) imager, which flies along with CERES on the Aqua spacecraft. MODIS is a 36-channel; 1-km, 500-m, and 250-m nadir resolution; narrowband scanner operating in crosstrack mode. To infer cloud properties, CERES uses a 1-km resolution MODIS radiance subset that has been subsampled to include only the data that corresponds to every second 1-km pixel and every second scanline. The Aqua SSF retains footprint imager radiance statistics for 5 of the 19 MODIS channels (SSF-115 through SSF-131). The Aqua Beta1 SSF contains footprint aerosol parameters from both the 10-km spatial resolution MODIS aerosol product (SSF-132 through SSF-160) and the NOAA/NESDIS algorithm (SSF-73 through SSF-78). Surface fluxes derived from the CERES instrument using several different techniques (algorithms) are also provided.

CERES defines SW (shortwave or solar) and LW (longwave or thermal infrared) in terms of physical origin, rather than wavelength. We refer to the solar radiation that enters or exits the Earth-atmosphere system as SW. LW is the thermal radiant energy emitted by the Earth-atmosphere system. Emitted radiation that is subsequently scattered is still regarded as LW. Roughly 1% of the incoming SW is at wavelengths greater than 4 µm. Less than 1 W m^{-2} of the OLR is at wavelengths smaller than 4 µm. The CERES unfiltered window (WN) radiance and flux represent emitted thermal radiation over the 8.1 to 11.8 µm wavelength interval.

The SSF product combines the absolute calibration and stability strengths of the broadband CERES radiation data with the high spectral and spatial resolution MODIS imager-based cloud and aerosol properties. A major advantage of the SSF over the traditional ERBE-like ES-8 TOA flux data product is the new angular models derived from TRMM CERES Rotating Azimuth Plane data that now allow accurate radiative fluxes not only for monthly mean regional ensembles (ERBE-like capability) but also as a function of cloud type. Fluxes in the CERES Aqua Beta1 SSF are based on CERES TRMM Edition2B Angular Direction Models (ADMs). A set of ADMS based on 2 years of CERES Terra measurements are under development and will be used to produce the CERES Aqua Edition1A SSFs scheduled for release in early-2004. With the new ADMs, accurate fluxes can be obtained for both optically thin clouds as a class, as well as optically thick clouds. This is a result of new empirical CERES TRMM angular models that classify clouds by optical depth, cloud fraction, and water/ice classes. ERBE-like TOA fluxes are only corrected for simple clear, partly-cloudy, mostly-cloudy, and overcast classes. In addition, clear-sky identification and clear-sky fluxes are expected to be much improved over the ERBE-like equivalent, because of the use of the imager cloud mask, as well as the new angular models incorporating ocean wind speed and surface vegetation class. Users of this product should take note that since the CERES

TRMM Edition2B ADMs were constructed using measurements in the tropics only, fluxes in the middle and upper latitudes will generally have larger uncertainties, particularly over snow and sea ice.

Finally, early estimates of surface radiative fluxes are given using relatively simple parameterizations applied to the SSF radiation and cloud parameters. These estimates strive for simplicity and as directly as possible use the TOA flux observations. More complex radiative transfer computations of surface and atmosphere fluxes using the SSF data and constrained to the observed SSF TOA fluxes will be provided on the CERES CRS Data Product. Expected delivery of the Aqua validated CRS product is late 2005. A beta version is expected to be available Fall 2003.

All CERES footprints containing one or more MODIS imager pixels are included on the SSF product. Since the MODIS imager can only scan to a maximum viewing zenith angle (VZA) of ~65°, this means that only CERES footprints with VZA < 67° are retained on the SSF when CERES is in the crosstrack scan mode. When CERES is scanning in either the Rotating Azimuth Plane (RAP) or the alongtrack scan mode, CERES footprints with VZA > 67° do appear on this product, provided they lie within the MODIS swath. The nominal CERES Aqua operation cycle for each instrument is 3 months in crosstrack scan mode followed by three months in RAP mode. The cycles of the two instruments are offset by three months such that there is always one instrument operating in the crosstrack scan mode and one in the RAP mode. Nominally, every fourteen days, the instrument operating in RAP mode switches to alongtrack scan mode for one day. To determine operations on any given day, refer to the CERES Operations in Orbit.

A full list of parameters on the SSF is contained in the SSF section of the CERES Data Products Catalog (PDF) and a definition of each parameter is contained in the SSF Collection Guide.

When referring to a CERES data set, please include the satellite name and/or the CERES instrument name, the data set version, and the data product. Multiple files that are identical in all aspects of the filename except for the 6 digit configuration code (see Collection Guide) differ little, if any, scientifically. Users may, therefore, analyze data from the same satellite/instrument, data set version, and data product without regard to configuration code. This data set may be referred to as "CERES Aqua FM4 Beta1 SSF" or simply the "CERES Aqua Beta1 SSF."

Cautions and Helpful Hints

There are numerous cautions the CERES Science Team notes regarding the use of CERES Aqua Beta1 SSF data:

General

- **These data are NOT regarded as publishable.**

- Before using SSF parameter values, users should check for CERES default values. CERES default values, or fill values, are very large values which vary by data type. (See SSF Collection Guide.) A CERES default value is used when the parameter value is unavailable or considered suspect. SSF-1 through SSF-24 always contain valid parameter values and, therefore, need not be checked for default values. All other parameter values should be checked.

- This SSF contains all CERES footprints with at least one imager pixel of coverage, even if that pixel could not be identified as clear or cloudy. This approach reduces regional biases in fluxes, but it puts more burden on the users to screen footprints according to their needs. For example, if one wants to relate CERES fluxes with imager-derived cloud properties (e.g. cloud fraction), it is very important to check SSF-54, "Imager percent coverage" (i.e., the percentage of the CERES footprint which could be identified as clear or cloudy). When none of the imager pixels within the footprint could be identified as clear or cloudy, the "imager percent coverage" is set to 0 and most imager derived SSF parameters are set to CERES default values. The SSF also contains a new flag that provides information on how much of the footprint contains pixels which could not be identified as clear or cloudy. This flag is referred to as "Unknown cloud-mask" and resides in SSF-64, "Notes on general procedures." Footprints with VZA greater than 80° and less than 100% imager coverage may be partial Earth-view. Consult SSF-34, "Radiance and Mode flags," to determine whether the footprint is full Earth-view or not. When the instrument is in the RAP or alongtrack scan mode, there are more footprints and the SSF files are larger. (See SSF Collection Guide.)

- The geographic location of a CERES flux estimate is at the surface geodetic latitude and longitude of the CERES footprint centroid. On ERBE, all fluxes are located at a geocentric latitude and longitude corresponding to the 30-km level.

- Users interested in surface type should always examine both SSF-25, "Surface type index," and SSF-26, "Surface type percent coverage. " (See SSF Collection Guide.)

- Users searching for footprints free of snow and ice should always examine both SSF-25, "Surface type index," and SSF-69, "Cloud-mask snow/ice percent coverage. " (See SSF Collection Guide.)

- A footprint is recorded in the hourly SSF file that contains its observation time. However, SSF footprints within the file are ordered on alongtrack angle, SSF-18, and not on time. The alongtrack angle of the satellite is defined to be 0° at the start of the hour. If the instrument is in the RAP or alongtrack scan mode, then footprints can be prior to this start position and yield a negative alongtrack angle.

- Some applications of the SSF data will need to make the distinction between crosstrack, RAP, and alongtrack scan data. Multiple scan modes can occur in the same hour so that bits 8-9 of SSF-34, "Radiance and Mode flags" (see SSF Collection Guide) should be examined for each footprint to properly identify the scan mode. If actual azimuth angle is required, examine SSF-15, "Clock angle of CERES FOV at satellite wrt inertial velocity."

Cloud

- Calibration - The calibrations of the Aqua MODIS channels used in the mask and cloud retrievals have not been rigorously examined yet.

- Cloud mask and phase selection - Because of severe problems with the Aqua MODIS 1.6-µm channel, the 2.13-µm channel reflectance has been used as a replacement for the 1.6-µm channel in all steps utilizing the 1.6-µm reflectance. Although preliminary clear-sky and surface parameters used in the cloud mask and phase selection have been derived for the 2.13-µm channel, the threshold values have not been thoroughly examined. Thus some errors in either the mask or phase selection may arise for some of the steps that originally used the 1.6-µm reflectance. Most of the decisions, except over snow primarily rely on other channels. The daytime polar mask using the 2.13-µm channel appears to produce results that are very comparable to those using the 1.6-µm channel.

- For Aqua Beta1 SSF, there is no algorithm for mean vertical aspect ratio. Therefore, SSF-111, Mean vertical aspect ratio for cloud layer (see SSF Collection Guide), should have been set to the CERES default fill value for all footprints. However, due to a software error, SSF-111 contains bogus values which should be ignored by all users.

- There are cases where the cloud properties cannot be determined for an imager pixel that is cloudy at a high confidence level. These pixels are included in the area coverage calculations. The cloud layer areas are proportionately adjusted to reflect the contribution these pixels would have made, but the cloud properties for each layer are not adjusted. The amount of extrapolation can be determined by checking SSF-63, "Cloud property extrapolation over cloud area." (See SSF Collection Guide.)

- Cloud parameters are saved by cloud layer. Up to two cloud layers may be recorded within a CERES footprint. The heights of the layers will vary from one footprint to another. When there is a single layer within the footprint, it is defined as the lower layer, regardless of its height. A second, or upper, layer is defined only when a footprint contains two unique layers. It is possible to have two unique cirrus layers or two unique layers below 4 km. Within an SSF file, the lower layer of one footprint may be much higher than the upper layer of another footprint.

- Night and near-terminator cloud properties - The current method for deriving cloud phase, particle size, and optical depth at night has not been fully tested. It has been implemented primarily to improve the nocturnal determination of cloud effective height for optically thin clouds ($\tau < 5$)and is generally effective at retrieving more accurate cloud heights compared to assuming that all clouds act as blackbody radiators at night. (See Cloud Properties Accuracy and Validation.) Because an accurate optical depth is required to obtain the proper altitude correction, the optical depths for optically thin clouds are considered reasonable.

- Near-terminator cloud amounts - The cloud mask relies heavily on the brightness temperature differences between channels 3 (3.7 µm) and 4 (10.8 µm) for identifying clouds at night (using 3.7-µm emittance) and in the daytime (using 3.7-µm reflectance). The signals differ between night and day for low clouds. For large solar zenith angles (> 80°), the emittance and reflectance signals can cancel each other, resulting in low clouds mistaken as clear areas when the cloud temperature is close to or warmer than the clear-sky temperature.

- Heavy aerosols - Aerosols with relatively large optical depths can sometimes be misidentified as clouds over any surface. Thus, in areas known to experience large dust outbreaks, such as large deserts or adjacent ocean areas, caution should be used when interpreting cloud statistics.

- Optical depths over snow - When it is known that the underlying surface is covered with snow or ice, cloud optical depth in Beta1 is derived using the SINT with the 2.13-µm radiance used in place of the 1.6-µm channel. Otherwise, the VISST is used, an approach that often results in an overestimate of the optical depth over snow. In general, the optical depths will be overestimated in snow-covered regions using the Beta1 algorithm if the underlying surface is not properly classified as being snow-covered.

- Phase selection/single-layered clouds - Because of ambiguities in the radiances for broken and optically thin clouds, pixels along the edges of supercooled water clouds will sometimes be classified as ice clouds.

- Multi-layered/mixed-phase cloud properties - Although an experimental product to detect multi-layered clouds was implemented in Beta1, its results have not been retained in SSF output because it requires additional study. Thus, all clouds are treated as single phase, single- layer clouds in the retrievals. Mixed phase cloud pixels are interpreted as either entirely liquid or ice clouds depending on the relative amounts of each phase in the top of a particular cloud. Overlapped ice and water cloud pixels will be interpreted in a similar fashion depending on the optical thickness and particle size of the overlying cloud. If it is very thin, the cloud will usually be classified as liquid. Thicker ice clouds over liquid clouds will be classified as ice. The resulting ice particle size for the thicker clouds should be representative of the ice cloud, but will often be too small for the thinner clouds. Mixed phase or overlapped thin-ice-over-thick-water clouds will produce either a liquid water effective radius that is too large for the water droplets in the cloud or too small for the ice crystals in the cloud because the 3.7 µm reflectances for the ice and water particles overlap at the low and high end, respectively. Users will need to use some contextual, temperature, or variability indicators to determine if a particular footprint contains both ice and water clouds if phase index for the footprint is either 1 (water) or 2 (ice). Cloud heights for multi-layered clouds will also be in error if the upper cloud deck is optically thin. The retrieved cloud altitude will be between the height of the lower and the upper clouds.

- "Mean cloud infrared emissivity for cloud layer," SSF-87, is an effective emissivity. Therefore, values greater than 1.0 may occur as a result of IR scattering within the cloud.

- Polar night cloud amounts - The Beta1 algorithm for detecting clouds over regions poleward of 60° tends to underestimate cloud fraction at night. Missed clouds in those areas can have a significant impact on the computed downwelling longwave flux.

- This SSF includes footprints over hot land and desert for which IR radiances are saturated. The WN brightness temperature is used to identify these scenes. Footprints containing these hot scenes are referred to as "reclassified clear" and flagged in SSF-65, "Notes on cloud algorithms." For "reclassified clear" footprints, most clear footprint area parameters, such as cloud mask percent coverages, aerosol A parameters, and imager-based surface skin temperature, are set to CERES default. (See SSF Collection Guide.)

Aerosol

- The Aqua Beta1 SSF contains footprint aerosol parameters from both MODIS (SSF-132 through SSF-160) and the NOAA/NESDIS algorithm (SSF-73 through SSF-78). The NOAA/NESDIS parameters provide continuity between the TRMM, Terra, and Aqua SSF data products. The MODIS aerosols are obtained from the MYD04_L2 product, version 3, which has a 10-km spatial resolution.

- The MODIS MYD04_L2 data product has renamed the dust weighting factor land to optical depth ratio small land. CERES was not aware of this change in time to make provisions for it. Therefore, all Aqua Beta1 values of SSF-135, PSF-wtd MOD04 dust weighting factor land, are set to the CERES default fill value. (See SSF Collection Guide.)

- Two NOAA/NESDIS aerosol optical depth parameters, τ_1 (SSF-73) and τ_2 (SSF-74), have been derived over oceans from MODIS bands centered at λ_1=0.659 µm and λ_2=1.640 µm using a AVHRR/VIRS-like single channel algorithm. The objective is to provide continuity with the NOAA/AVHRR and TRMM/VIRS analyses, and to check the consistency of the simplistic "NOAA" retrievals against more sophisticated MODIS aerosols (SSF-146 through SSF-160). The user not involved in those activities is advised to use the MODIS aerosol product which is expected to be more accurate. Additionally, the NOAA-like parameters for TERRA have not been validated and thoroughly tested yet. From τ_1 and τ_2, the Angstrom exponent is estimated as $\alpha = -\ln (\tau_1 / \tau_2)/\ln (\lambda_1 / \lambda_2)$. Note that errors in α change in inverse proportion to τ (Ignatov and Stowe 2000, 2002b).

- There are trends in the NOAA/NESDIS aerosol retrieval which use this algorithm and VIRS or AVHRR imager data. These trends exist with different sun-view angles, precipitable water, wind speed, and infrared radiance (Ignatov and Nalli 2002). Some of the trends are deemed to be artifacts of the retrieval algorithm, and yet some may be real. In particular, trends with wind speed may suggest that ocean specular reflection or white caps may be artificially elevating aerosol optical depth values. Trends with cloud cover may result from either weak cloud contamination (possibly from cirrus cloud, as noted above), or from real changes in aerosol properties due to the clouds (indirect effect). At the time of this writing, no MODIS studies have been done. However, since trends in aerosol retrievals were observed for VIRS and AVHRR, they probably also exist for MODIS.

- NOAA/NESDIS aerosol retrievals (SSF-73 and SSF-74) are reported on the SSF when the solar zenith angle, SSF-21, is less than 70°. For TRMM SSF data sets, which use VIRS imager data, pronounced biases in retrievals start developing for solar zenith angles > 60° (Ignatov and Nalli 2002; Ignatov and Stowe 2002a). At the time of this writing, no MODIS studies have been done. However, it is thought that similar biases may also occur when using MODIS data as input. At this time, use of aerosol retrievals when solar zenith angles exceed 60° is not recommended.

- NOAA/NESDIS visible and near-IR aerosol optical depths (SSF-73 and SSF-74) are retrieved only over ocean. Despite severe problems with the Aqua MODIS 1.6 µm channel, its use was continued in the aerosol algorithm. Given the homogenity of aerosol over small areas, the loss information should not result in significant variation in the values. For a discussion of which pixels are used, refer to Aerosol Properties - Accuracy and Validation.

TOA Flux

- During the daytime, the CERES LW TOA flux - upward (SSF-39) is too high by approximately 9% of the CERES SW TOA flux - upward (SSF-38). This is due to an error in spectral correction and will be corrected in the next version of the Aqua SSF data.

- The CERES TRMM Edition2B angular models (see TOA Fluxes section) are a marked advance over anything previously available, and allow determination of accurate TOA fluxes for a wide range of cloud and aerosol conditions. These fluxes will be most accurate when a class of cloud or clear-sky is averaged over a wide range of viewing zenith angles. Not all anisotropy has been removed, and for highest accuracy users are advised to avoid restricting viewing zenith angles to a narrow range (just near nadir for example).

- The CERES TRMM Edition2B angular models were constructed using measurements in the tropics only. Therefore, fluxes in the middle and upper latitudes will generally have larger uncertainties, particularly over snow and sea ice.

Surface Flux

- The CERES downward LW surface flux - Model A (SSF-42) and CERES net LW surface flux - Model A (SSF-45) have corresponding biases to the CERES LW TOA flux - upward (SSF-39).

- Shortwave Model A and Longwave Model A surface fluxes (SSF-41 through SSF-45) are limited to footprints with clear area coverage (SSF-66) of 99.9% or more. Shortwave Model B and Longwave Model B surface fluxes (SSF-46 through SSF-49), however, are available for all-sky.

Accuracy and Validation

Accuracy and validation discussions are organized into sections.

Please read those sections which correspond to parameters of interest.

- Cloud properties
- Aerosol properties
- Spatial matching of imager properties and broadband radiation
- TOA fluxes
- Surface fluxes

Expected Reprocessing

Aqua Edition1A SSF, a validated data set, is expected in early 2004.

Referencing Data in Journal Articles

These data are NOT for publication.

Feedback

For questions or comments on the CERES Quality Summary, contact the User and Data Services staff at the Atmospheric Science Data Center.

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